FIG. 1

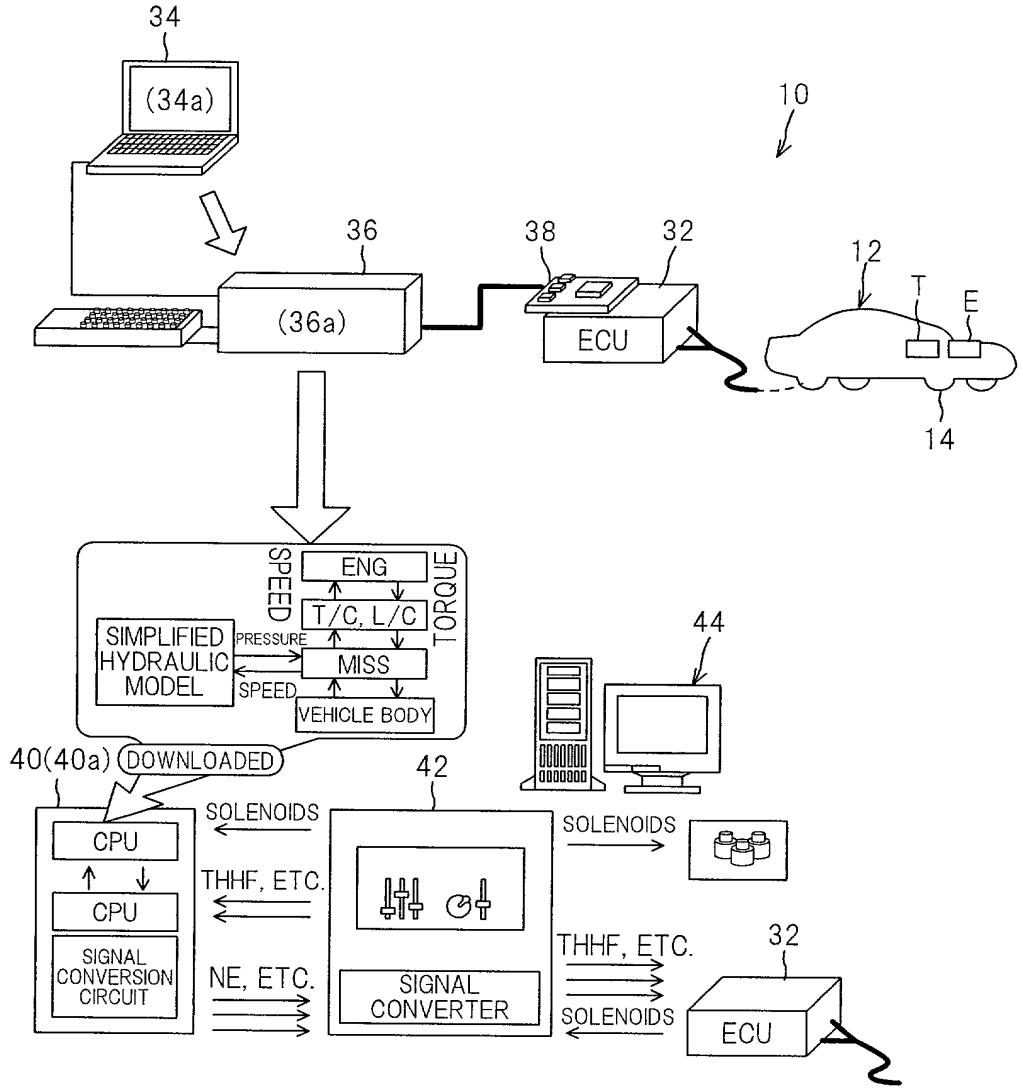
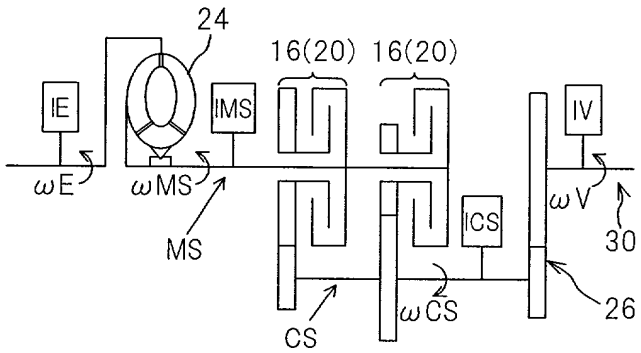

34
(34a)
10
36
38
32
12
T
E
(36a)
ECU
14
SPEED
ENG
T/C, L/C
MISS
VEHICLE BODY
TORQUE
SIMPLIFIED HYDRAULIC MODEL
PRESSURE
SPEED
44
40(40a)
DOWNLOADED
42
SOLENOIDS
CPU
CPU
SIGNAL CONVERSION CIRCUIT
THHF, ETC.
NE, ETC.
SIGNAL CONVERTER
SOLENOIDS
THHF, ETC.
SOLENOIDS
32
ECU

FIG. 2



$$TE-TP-IE\cdot\dot{\omega}E=0 \quad (1)$$

$$TP=\tau\cdot((\omega E/2\pi)\cdot 60/1000)^2 \quad (2)$$

$$TMS=k\cdot TP \quad (3)$$

$$TMS-TL-TH-IMS\cdot\dot{\omega}MS=0 \quad (4)$$

$$TCS-TL\cdot iL-TH\cdot iH+ICS\cdot\dot{\omega}CS=0 \quad (5)$$

$$TDS=TCS\cdot IF \quad (6)$$

$$TDS-TV-IDS\cdot\dot{\omega}V=0 \quad (7)$$

ICS: COUNTERSHAFT INERTIA MOMENT
IE: ENGINE INERTIA MOMENT
IMS: MAIN SHAFT INERTIA MOMENT
IV: MOMENT CORRESPONDING TO VEHICLE INERTIA
IDS: DRIVESHAFT INERTIA MOMENT
iF: FINAL REDUCED GEAR RATIO
iH: GEAR RATIO TO BE SHIFTED TO
iL: GEAR RATIO SHIFTED FROM
ωCS: COUNTERSHAFT SPEED
ωE: ENGINE SPEED
ωMS: MAIN SHAFT SPEED
ωV: DRIVESHAFT SPEED
TCS: COUNTERSHAFT TORQUE
TE: ENGINE TORQUE
TH: TRANSMISSION TORQUE OF CLUTCH TO BE SHIFTED TO
TMS: MAIN SHAFT TORQUE
TL: TRANSMISSION TORQUE OF CLUTCH SHIFTED FROM
TP: TORQUE CONVERTER'S PUMP MEMBER TORQUE
TV: RUNNING RESISTANCE
TDS: DRIVESHAFT TORQUE
k: TORQUE CONVERTER'S TORQUE RATIO
τ: TORQUE CONVERTER'S PUMP ABSORPTION TORQUE AMOUNT COEFFICIENT

PHASE	MAIN SHAFT MS	COUNTERSHAFT CS
LOW-GEAR DRIVING	$TMS=TL$ (8)	$TCS=TMS\cdot iL$ (9)
TORQUE PHASE	$TMS=TH+TL$ (10)	$TCS=TMS\cdot iL-TH\cdot(iL-iH)$ (11)
INERTIA PHASE	$TMS=TH-IMS\cdot\dot{\omega}MS$ (12)	$TCS=TH\cdot iH$ (13)
HIGH-GEAR DRIVING	$TMS=TH$ (14)	$TCS=TMS\cdot iH$ (15)

FIG. 3

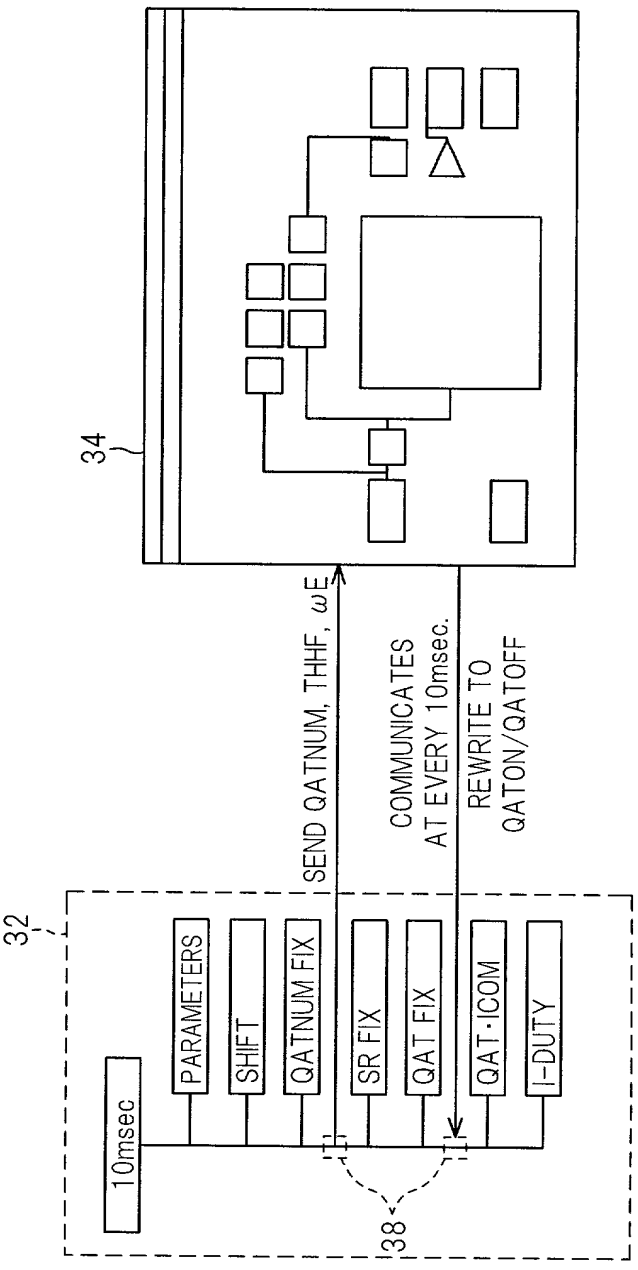
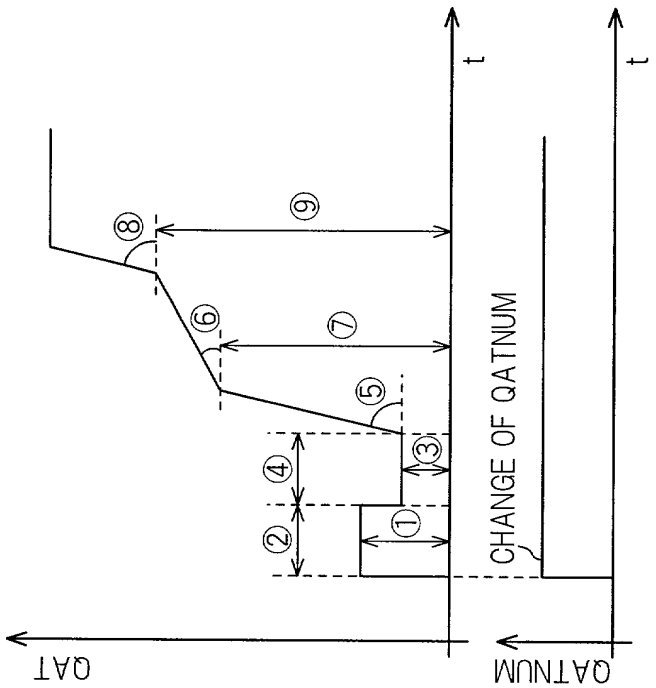
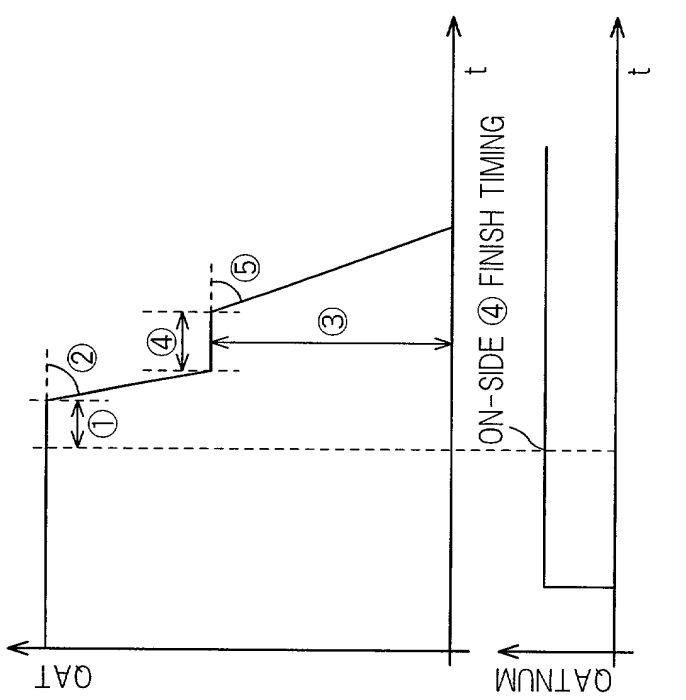

34
32
10msec
PARAMETERS
SHIFT
QATNUM FIX
SR FIX
QAT FIX
QAT·ICOM
I-DUTY
38
SEND QATNUM, THHF, ωE
COMMUNICATES AT EVERY 10msec.
REWRITE TO QATON/QATOFF

FIG. 4



PORTION	COMMAND	UNIT
①	INITIAL PRESSURE	kg/cm^2
②	TIME FOR PLAY-REMOVING CLUTCH PISTON STROKE	sec
③	PREPARATORY PRESSURE	kg/cm^2
④	PREPARATORY PRESSURE KEEPING TIME	sec
⑤	ON-SIDE PRESSURE RISING SPEED	$kg/cm^2/sec$
⑥	FIRST DESIRED ON-SIDE PRESSURE	kg/cm^2
⑦	ON-SIDE PRESSURE RISING SPEED	$kg/cm^2/sec$
⑧	SECOND DESIRED ON-SIDE PRESSURE	kg/cm^2
⑨	ON-SIDE PRESSURE RISING SPEED	$kg/cm^2/sec$

FIG. 5



PORTION	COMMAND	UNIT
①	PREPARATORY TIME	sec
②	OFF-SIDE PRESSURE DROPPING SPEED	$kg/cm^2/sec$
③	DESIRED OFF-SIDE PRESSURE	kg/cm^2
④	OFF-SIDE PRESSURE KEEPING TIME	sec
⑤	OFF-SIDE PRESSURE DROPPING SPEED	$kg/cm^2/sec$

FIG. 6

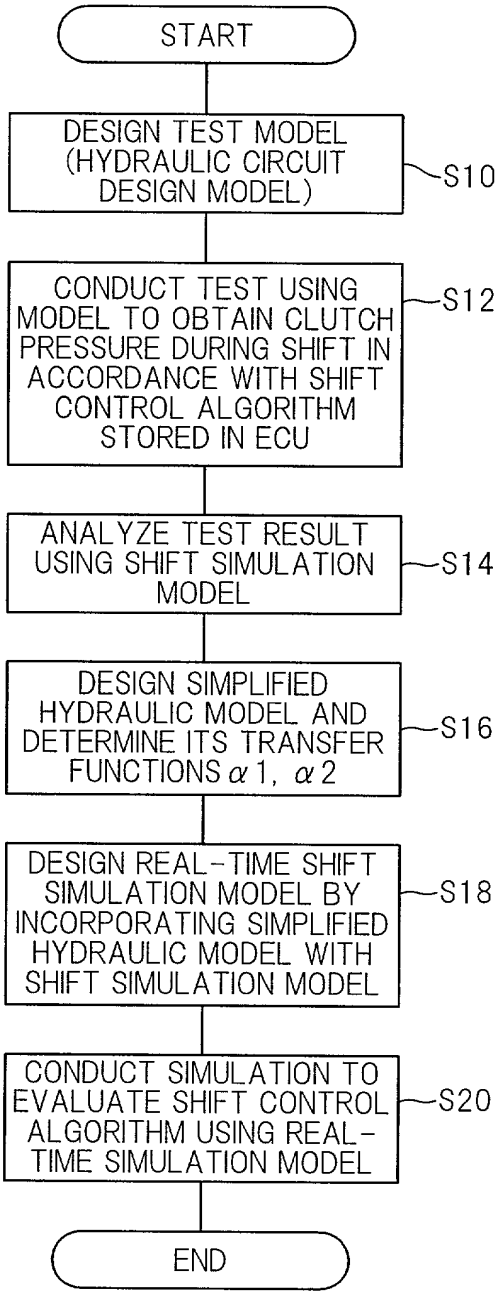

START
DESIGN TEST MODEL (HYDRAULIC CIRCUIT DESIGN MODEL)
S10
CONDUCT TEST USING MODEL TO OBTAIN CLUTCH PRESSURE DURING SHIFT IN ACCORDANCE WITH SHIFT CONTROL ALGORITHM STORED IN ECU
S12
ANALYZE TEST RESULT USING SHIFT SIMULATION MODEL
S14
DESIGN SIMPLIFIED HYDRAULIC MODEL AND DETERMINE ITS TRANSFER FUNCTIONS α1, α2
S16
DESIGN REAL-TIME SHIFT SIMULATION MODEL BY INCORPORATING SIMPLIFIED HYDRAULIC MODEL WITH SHIFT SIMULATION MODEL
S18
CONDUCT SIMULATION TO EVALUATE SHIFT CONTROL ALGORITHM USING REAL-TIME SIMULATION MODEL
S20
END

FIG. 7

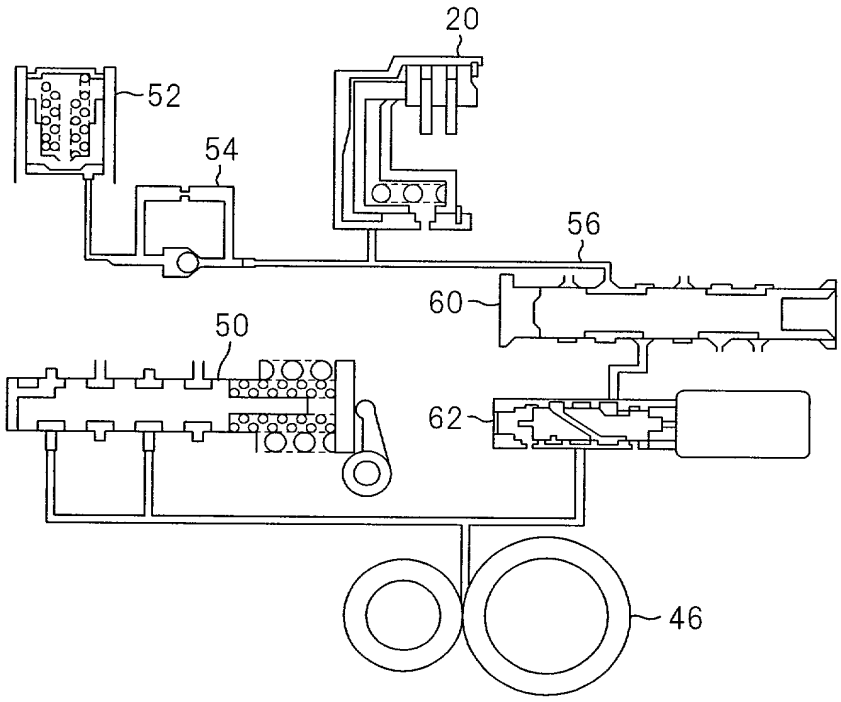


FIG. 8

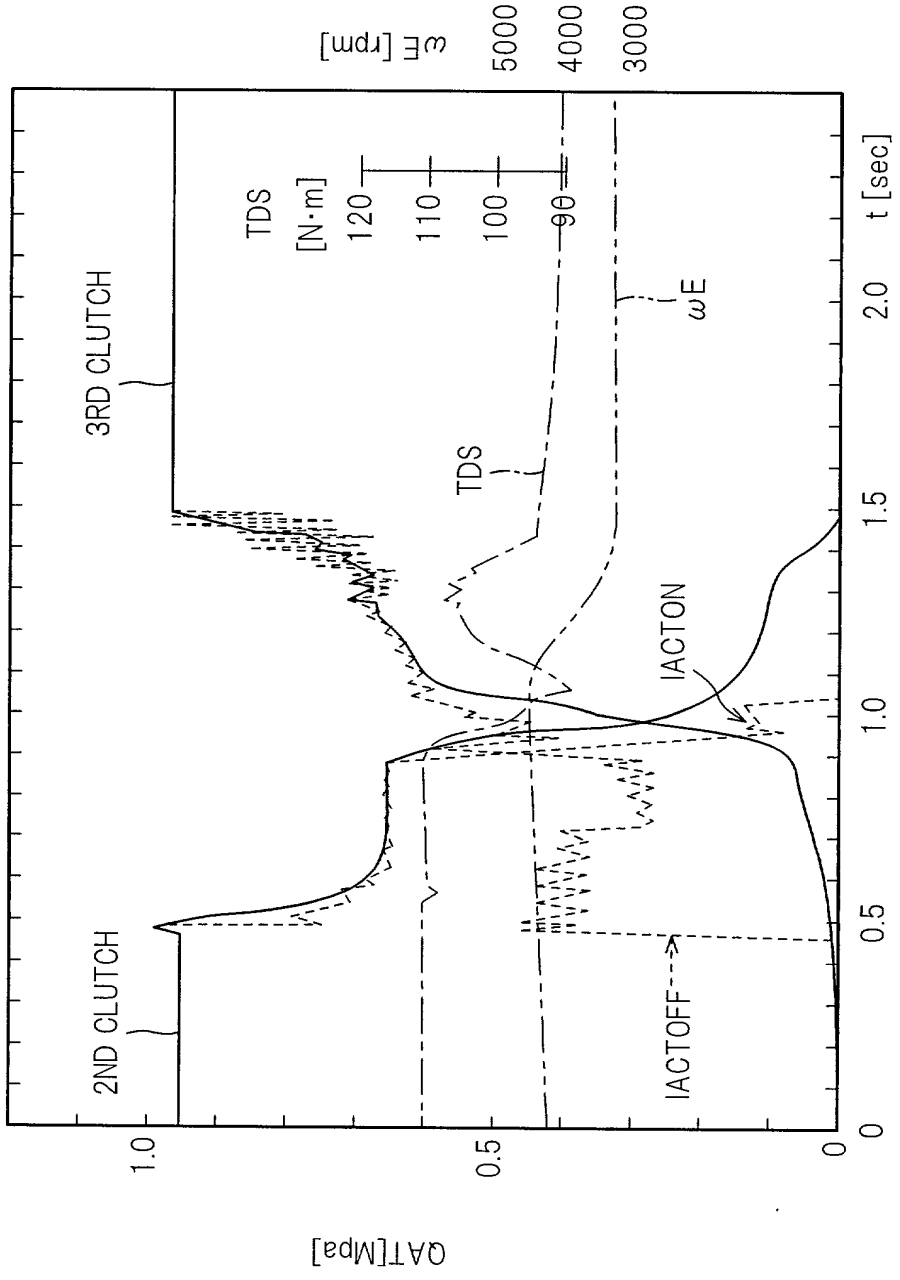

ΔT[Mpa]
1.0
0.5
0
ωE [rpm]
5000
4000
3000
TDS
[N·m]
120
110
100
90
2ND CLUTCH
3RD CLUTCH
TDS
ωE
IACTON
IACTOFF
0
0.5
1.0
1.5
2.0
t [sec]

FIG. 9

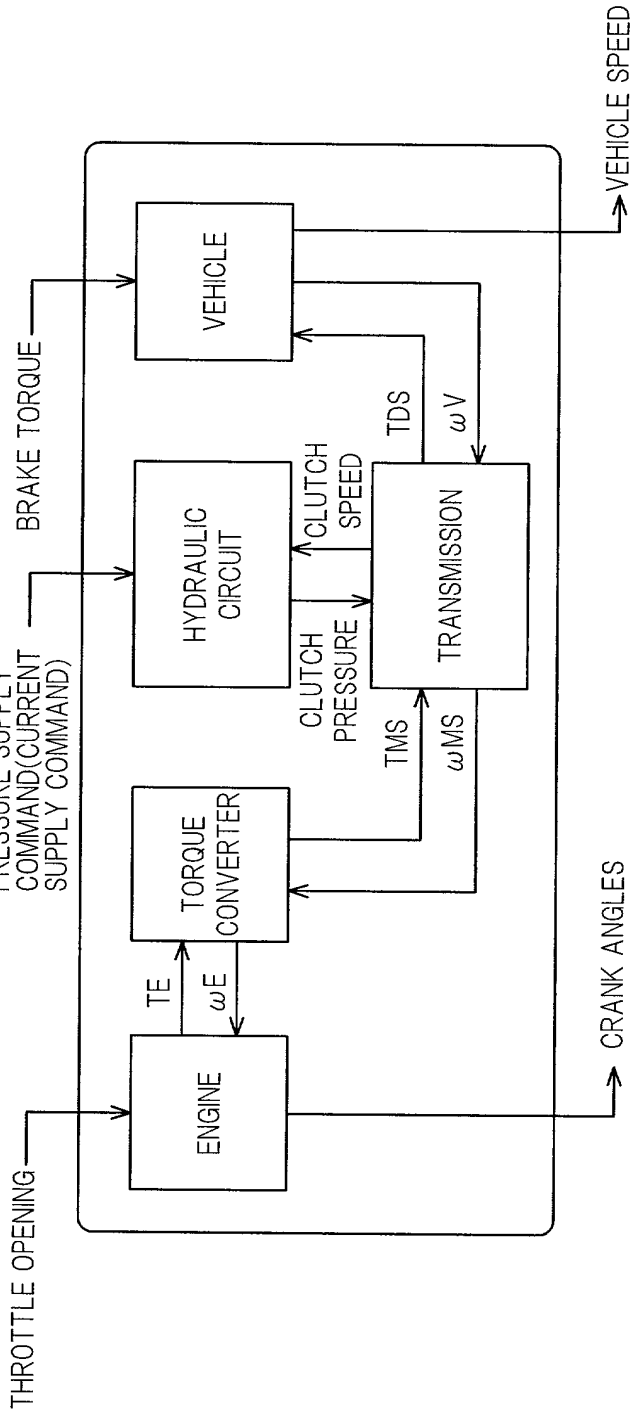

THROTTLE OPENING
HYDRAULIC PRESSURE SUPPLY COMMAND(CURRENT SUPPLY COMMAND)
BRAKE TORQUE
ENGINE
TORQUE CONVERTER
HYDRAULIC CIRCUIT
VEHICLE
TRANSMISSION
TE
ωE
TMS
ωMS
CLUTCH PRESSURE
CLUTCH SPEED
TDS
ωV
CRANK ANGLES
VEHICLE SPEED

FIG. 10

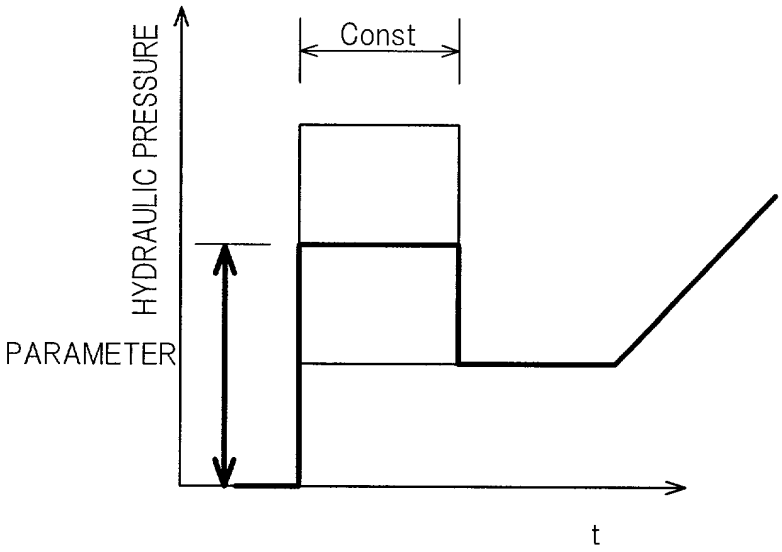


FIG. 11

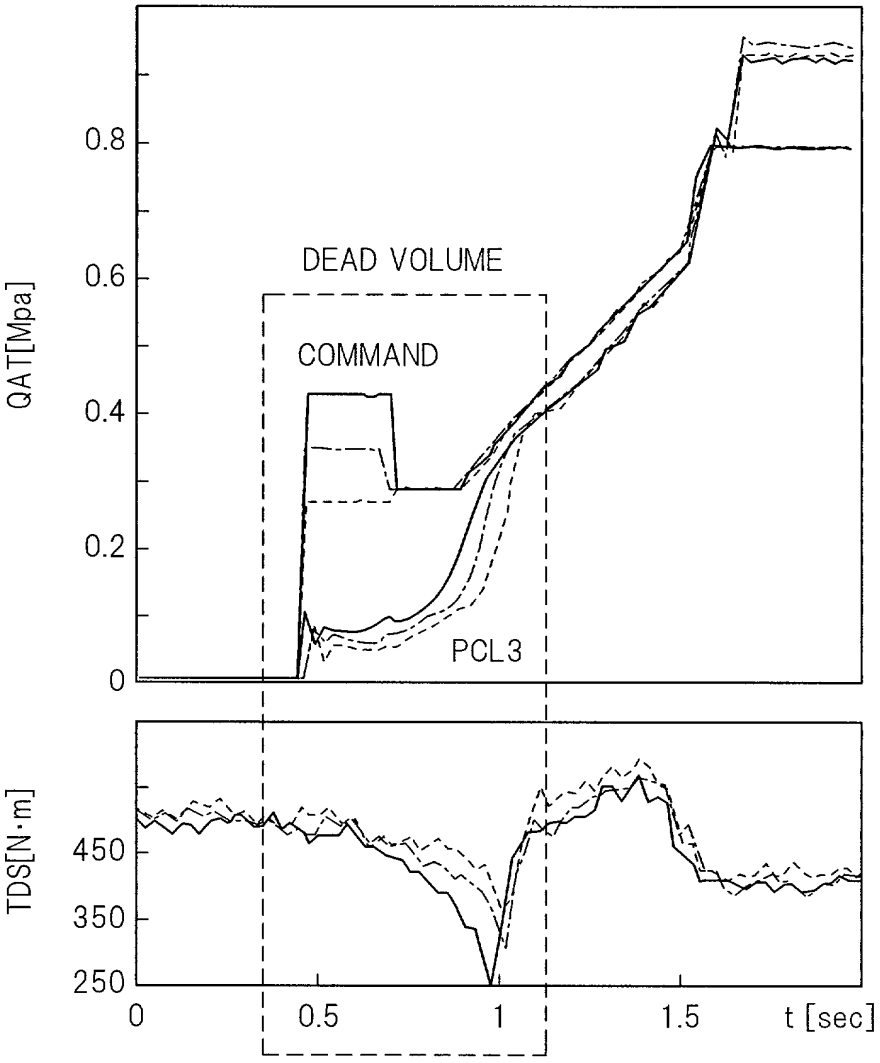

0.8
0.6
0.4
0.2
0
QAT[Mpa]
DEAD VOLUME
COMMAND
PCL3
450
350
250
TDS[N·m]
0
0.5
1
1.5
t [sec]

FIG. 12

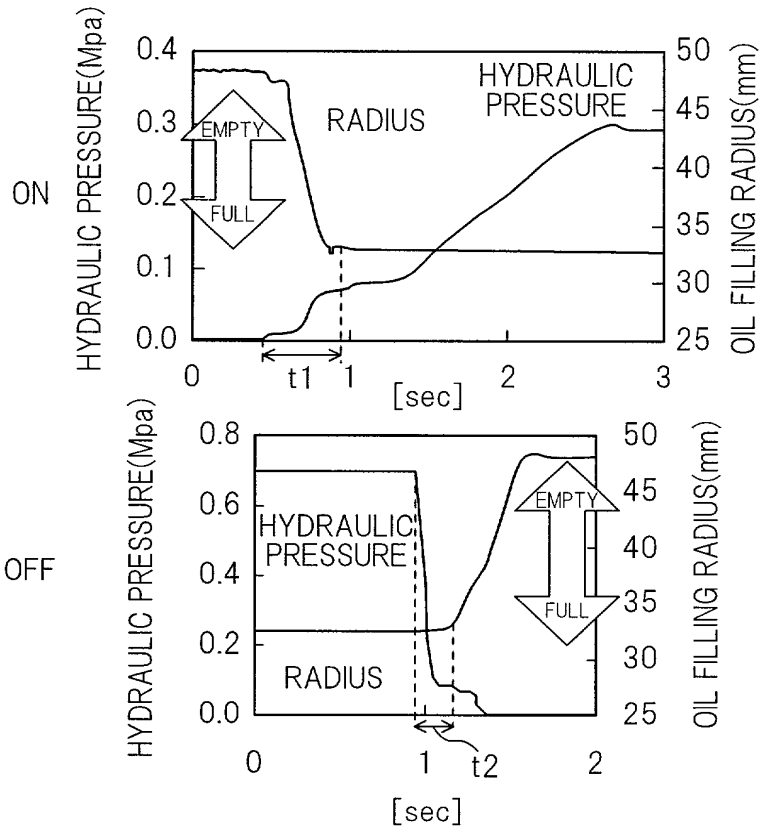

ON
HYDRAULIC PRESSURE(Mpa)
0.4
0.3
0.2
0.1
0.0
EMPTY
FULL
RADIUS
HYDRAULIC PRESSURE
50
45
40
35
30
25
OIL FILLING RADIUS(mm)
0
t1
1
2
3
[sec]
OFF
HYDRAULIC PRESSURE(Mpa)
0.8
0.6
0.4
0.2
0.0
HYDRAULIC PRESSURE
RADIUS
EMPTY
FULL
50
45
40
35
30
25
OIL FILLING RADIUS(mm)
0
1
t2
2
[sec]

FIG. 13

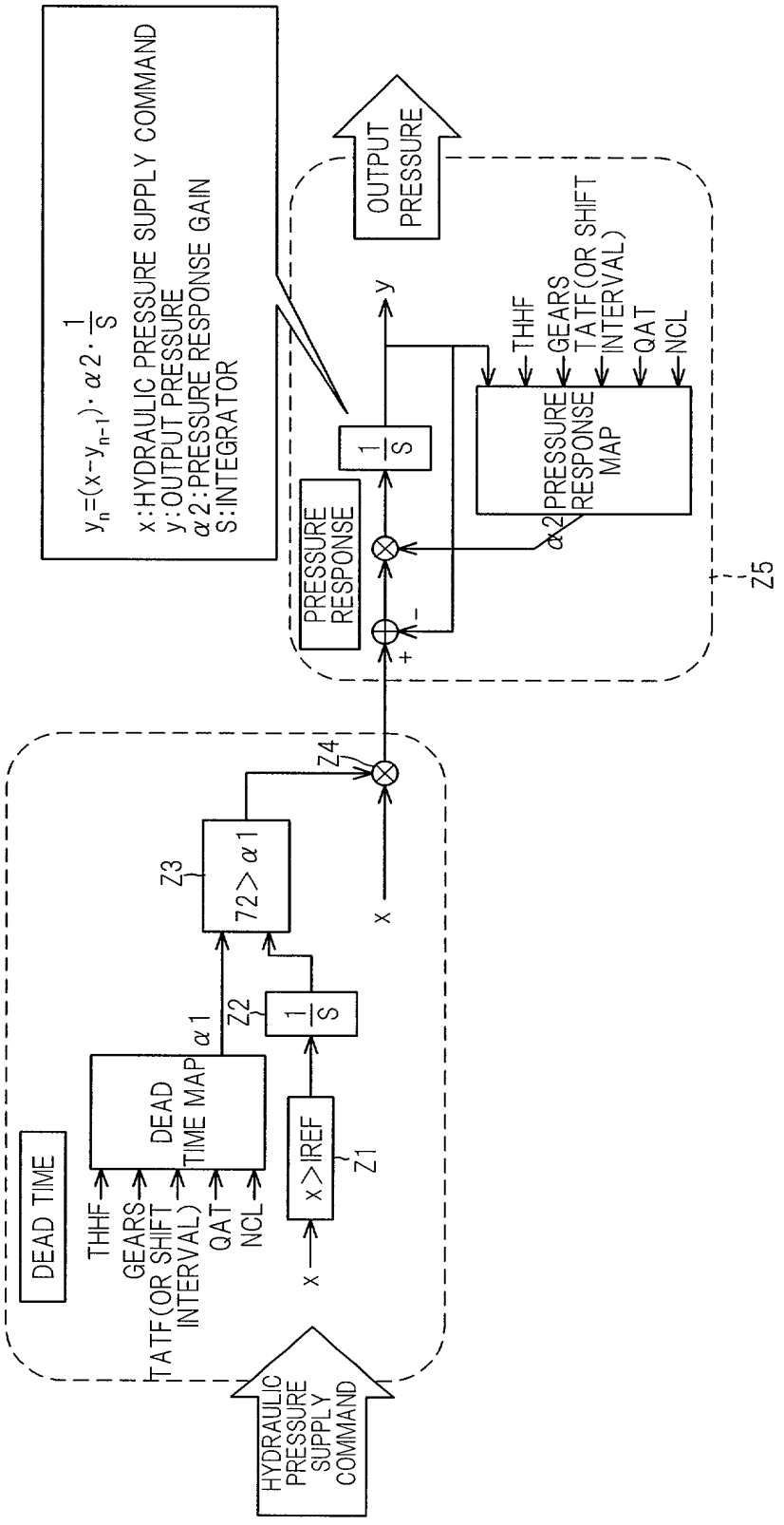

$y_n=(x-y_{n-1})\cdot\alpha 2\cdot\frac{1}{S}$
x:HYDRAULIC PRESSURE SUPPLY COMMAND
y:OUTPUT PRESSURE
α2:PRESSURE RESPONSE GAIN
S:INTEGRATOR
OUTPUT PRESSURE
HYDRAULIC PRESSURE SUPPLY COMMAND
DEAD TIME
THHF
GEARS
TATF(OR SHIFT INTERVAL)
QAT
NCL
DEAD TIME MAP
α1
x>IREF
Z1
Z2
1/S
Z3
72>α1
Z4
x
y
PRESSURE RESPONSE
1/S
α2 PRESSURE RESPONSE MAP
Z5

FIG. 14

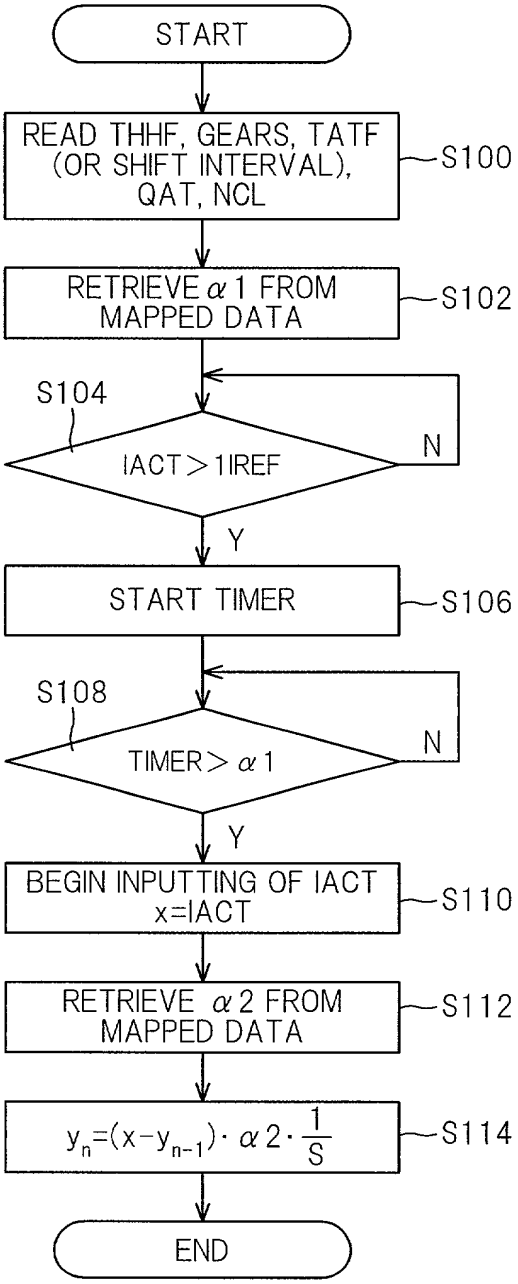

START
READ THHF, GEARS, TATF (OR SHIFT INTERVAL), QAT, NCL
S100
RETRIEVE α1 FROM MAPPED DATA
S102
S104
IACT>1IREF
N
Y
START TIMER
S106
S108
TIMER> α1
N
Y
BEGIN INPUTTING OF IACT x=IACT
S110
RETRIEVE α2 FROM MAPPED DATA
S112
$y_n=(x-y_{n-1})\cdot\alpha 2\cdot\frac{1}{S}$
S114
END

FIG. 15A

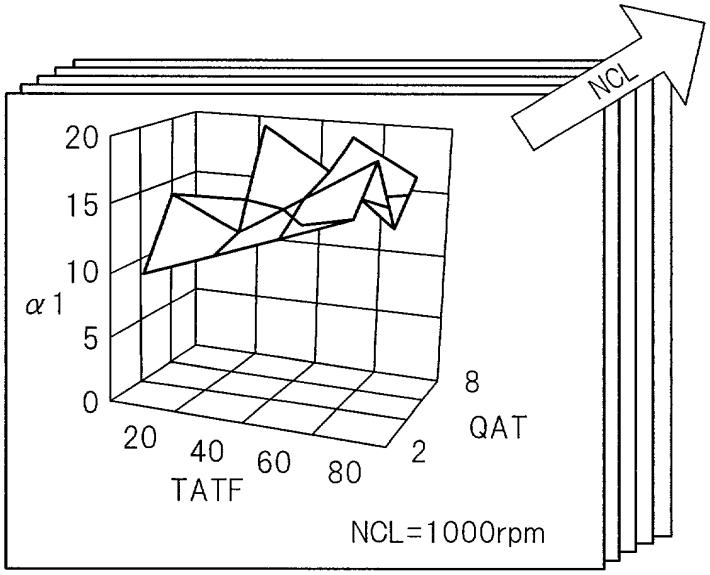


FIG. 15B

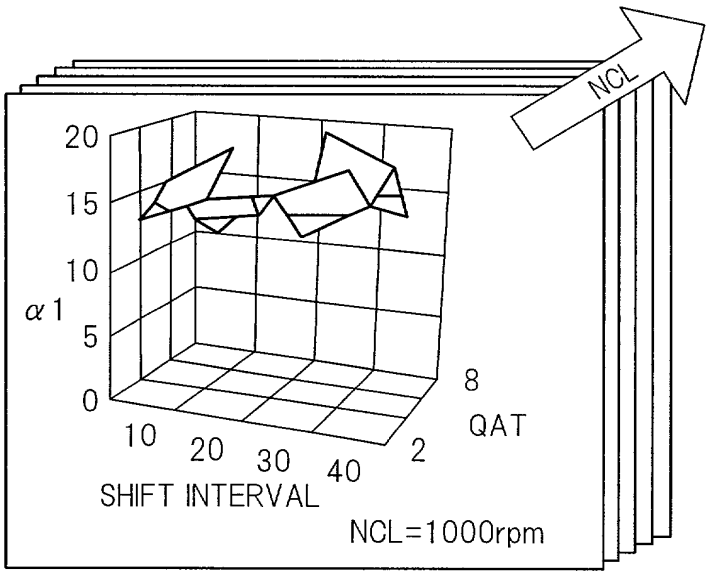


FIG. 16A

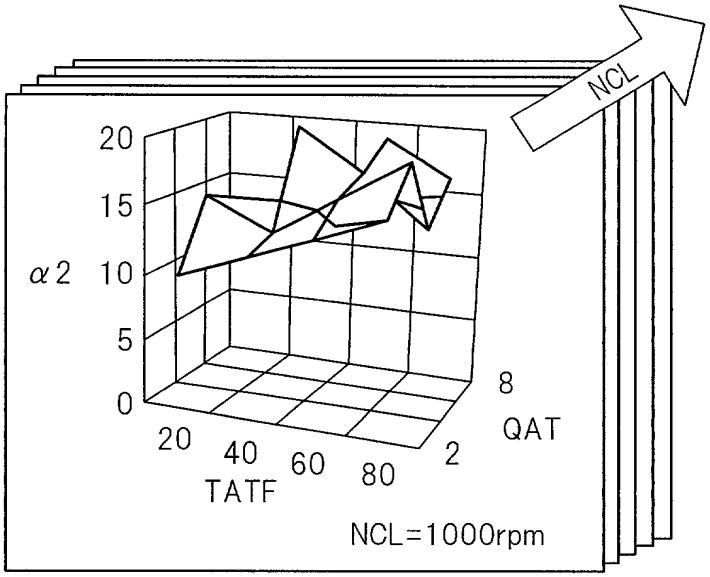


FIG. 16B

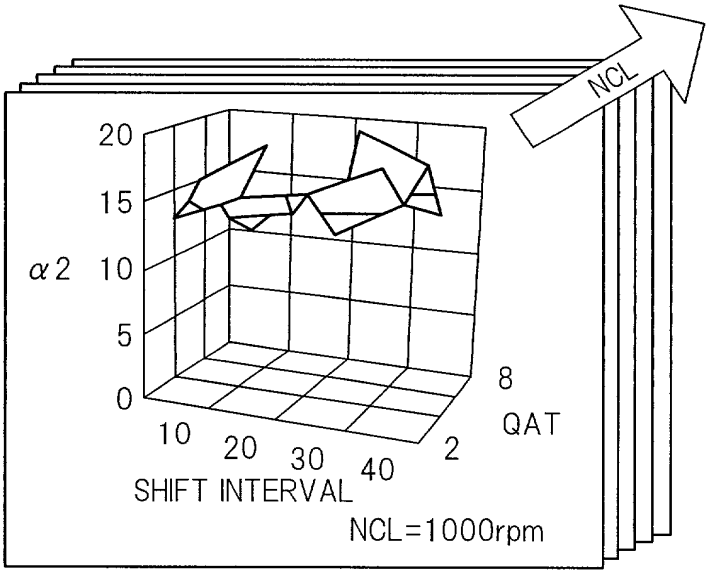


FIG. 17

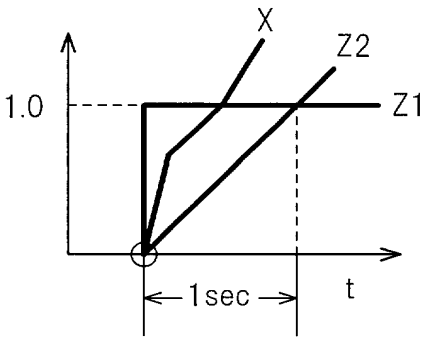


FIG. 18

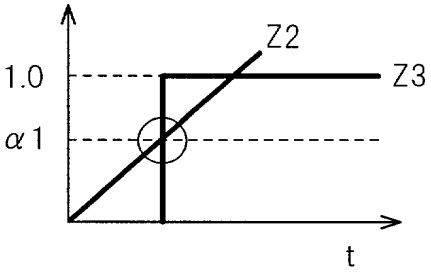


FIG. 19

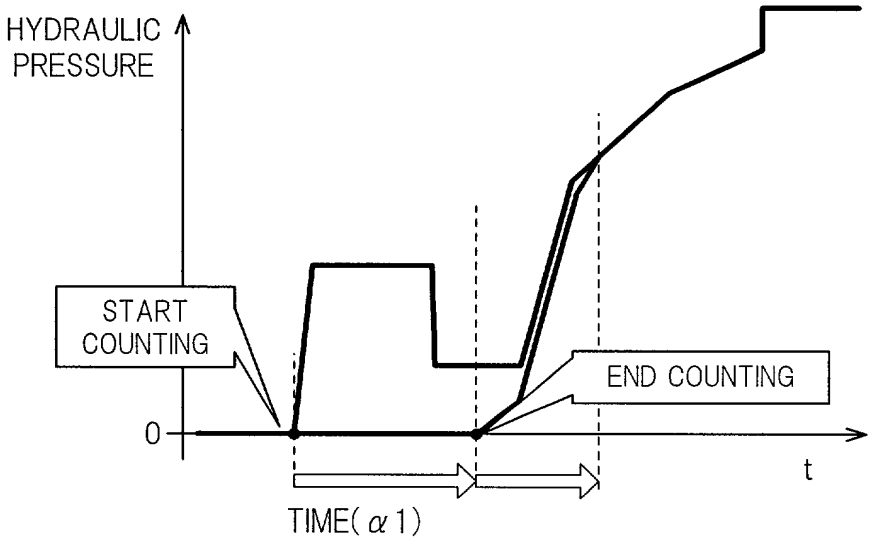


FIG. 20

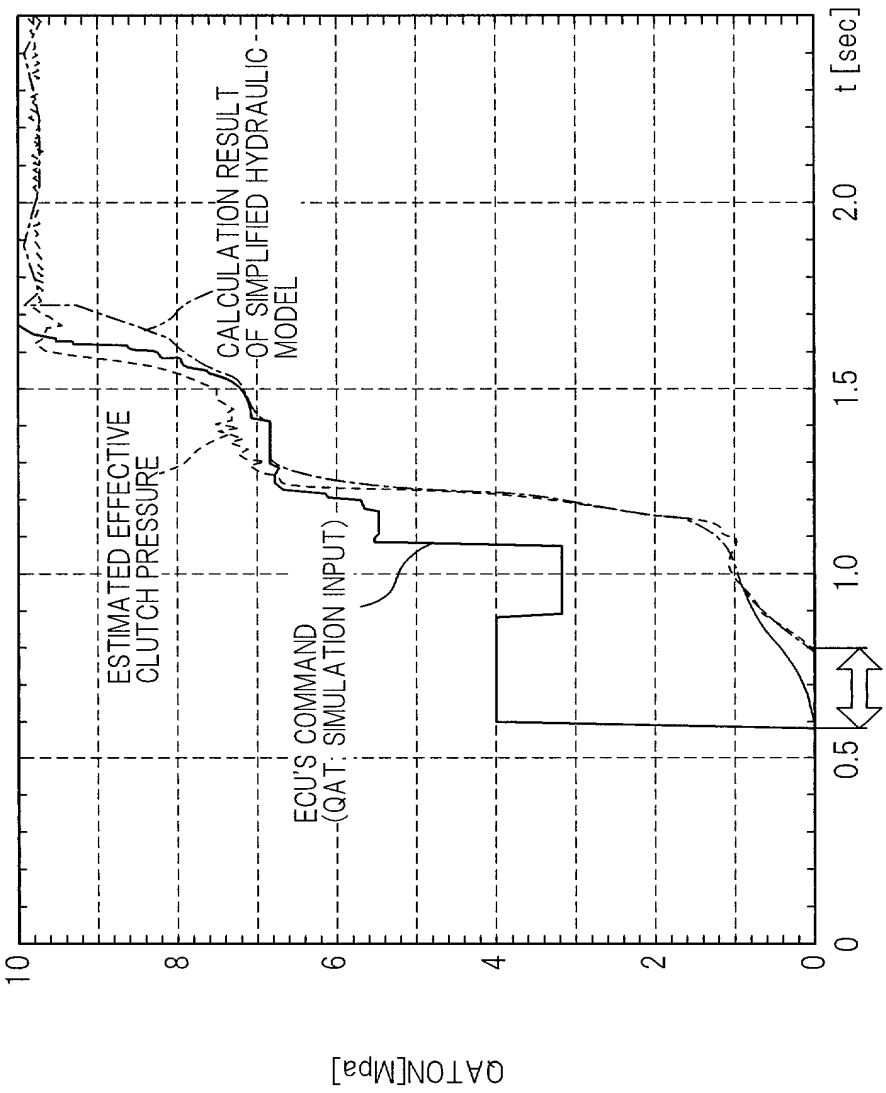

ESTIMATED EFFECTIVE CLUTCH PRESSURE
CALCULATION RESULT OF SIMPLIFIED HYDRAULIC MODEL
ECU'S COMMAND (QAT: SIMULATION INPUT)
PREDETERMINED TIME
t [sec]
QATON[Mpa]
0
2
4
6
8
10
0.5
1.0
1.5
2.0

FIG. 21

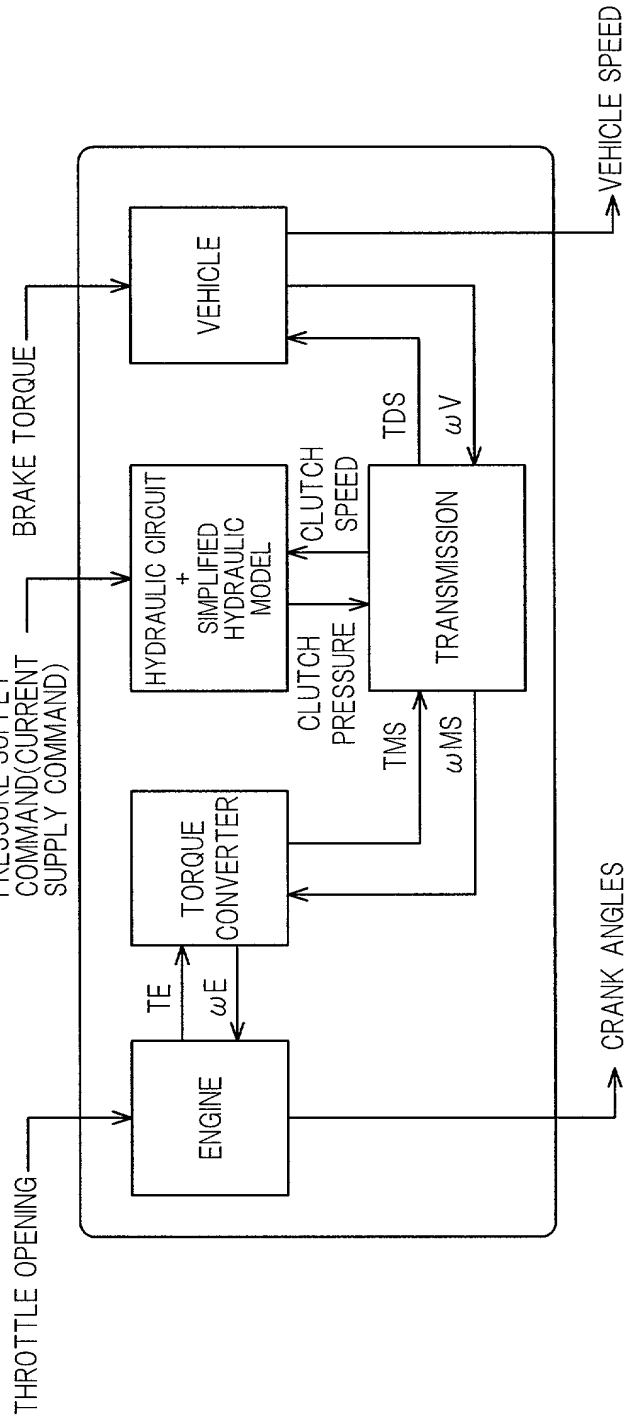

THROTTLE OPENING
HYDRAULIC PRESSURE SUPPLY COMMAND(CURRENT SUPPLY COMMAND)
BRAKE TORQUE
ENGINE
TE
ωE
TORQUE CONVERTER
HYDRAULIC CIRCUIT + SIMPLIFIED HYDRAULIC MODEL
VEHICLE
TMS
ωMS
CLUTCH PRESSURE
CLUTCH SPEED
TDS
ωV
TRANSMISSION
CRANK ANGLES
VEHICLE SPEED

FIG. 22

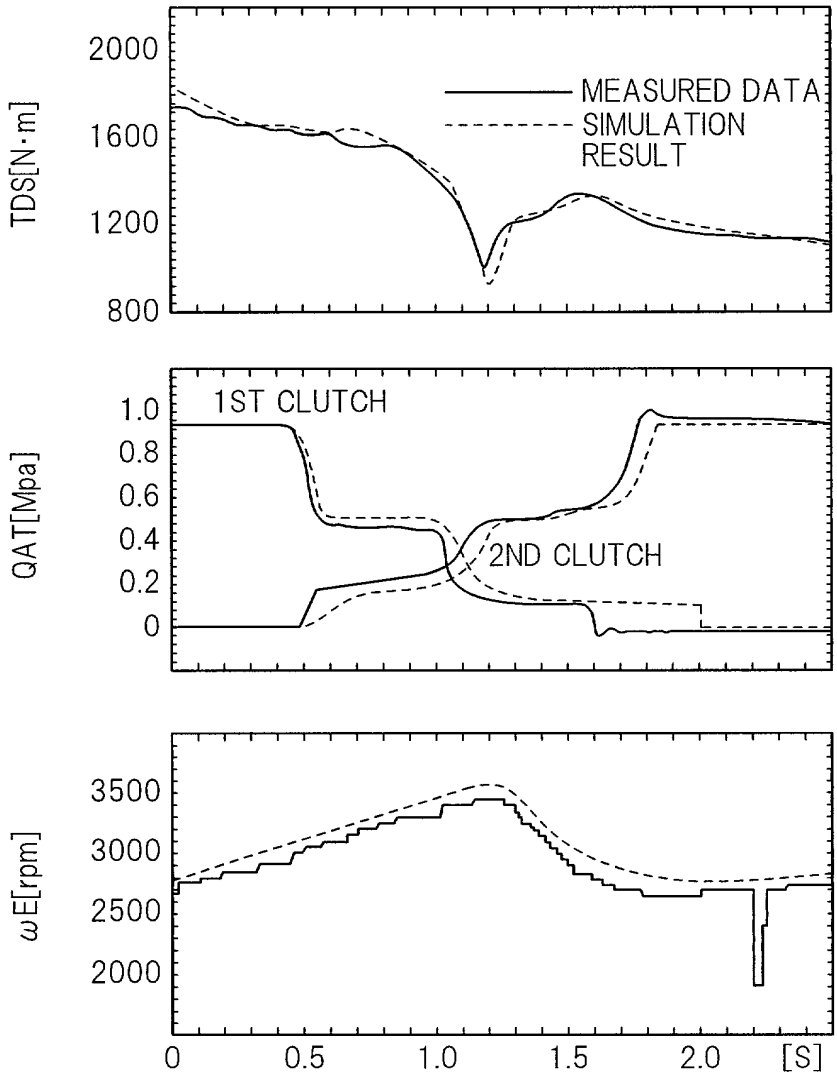

TDS[N·m]
2000
1600
1200
800
MEASURED DATA
SIMULATION RESULT
QAT[Mpa]
1.0
0.8
0.6
0.4
0.2
0
1ST CLUTCH
2ND CLUTCH
ωE[rpm]
3500
3000
2500
2000
0
0.5
1.0
1.5
2.0
[S]

FIG. 23

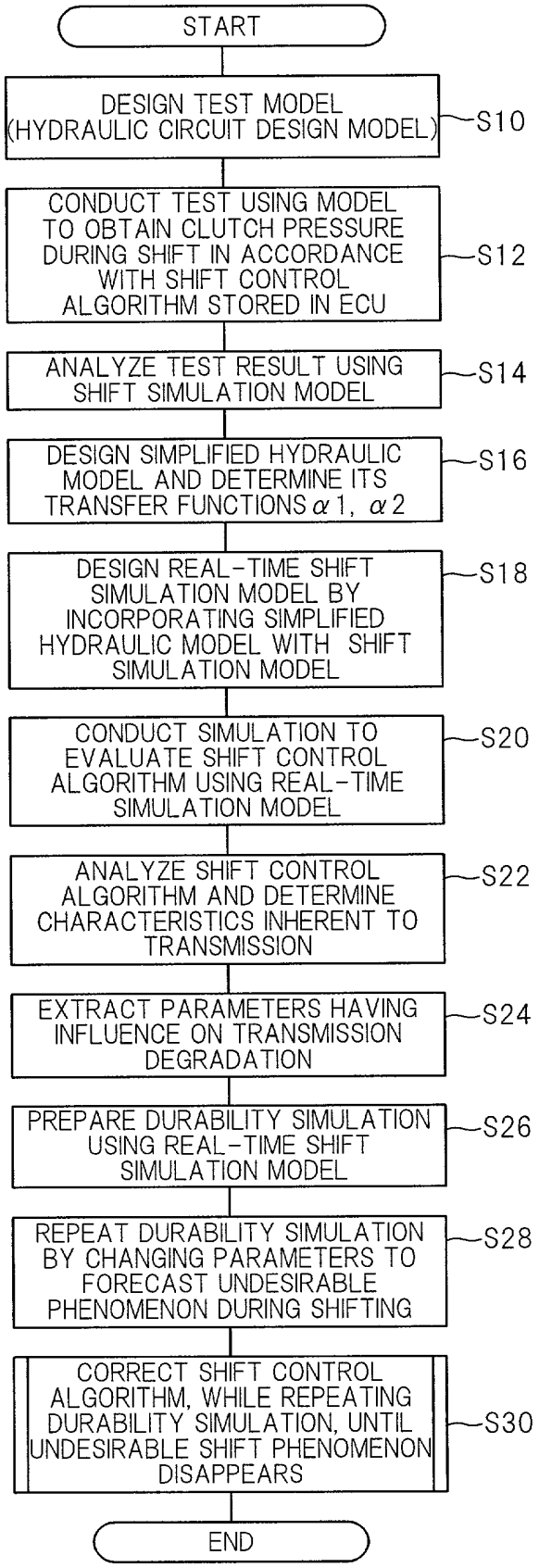

START
DESIGN TEST MODEL (HYDRAULIC CIRCUIT DESIGN MODEL)
S10
CONDUCT TEST USING MODEL TO OBTAIN CLUTCH PRESSURE DURING SHIFT IN ACCORDANCE WITH SHIFT CONTROL ALGORITHM STORED IN ECU
S12
ANALYZE TEST RESULT USING SHIFT SIMULATION MODEL
S14
DESIGN SIMPLIFIED HYDRAULIC MODEL AND DETERMINE ITS TRANSFER FUNCTIONS α1, α2
S16
DESIGN REAL-TIME SHIFT SIMULATION MODEL BY INCORPORATING SIMPLIFIED HYDRAULIC MODEL WITH SHIFT SIMULATION MODEL
S18
CONDUCT SIMULATION TO EVALUATE SHIFT CONTROL ALGORITHM USING REAL-TIME SIMULATION MODEL
S20
ANALYZE SHIFT CONTROL ALGORITHM AND DETERMINE CHARACTERISTICS INHERENT TO TRANSMISSION
S22
EXTRACT PARAMETERS HAVING INFLUENCE ON TRANSMISSION DEGRADATION
S24
PREPARE DURABILITY SIMULATION USING REAL-TIME SHIFT SIMULATION MODEL
S26
REPEAT DURABILITY SIMULATION BY CHANGING PARAMETERS TO FORECAST UNDESIRABLE PHENOMENON DURING SHIFTING
S28
CORRECT SHIFT CONTROL ALGORITHM, WHILE REPEATING DURABILITY SIMULATION, UNTIL UNDESIRABLE SHIFT PHENOMENON DISAPPEARS
S30
END

FIG. 24

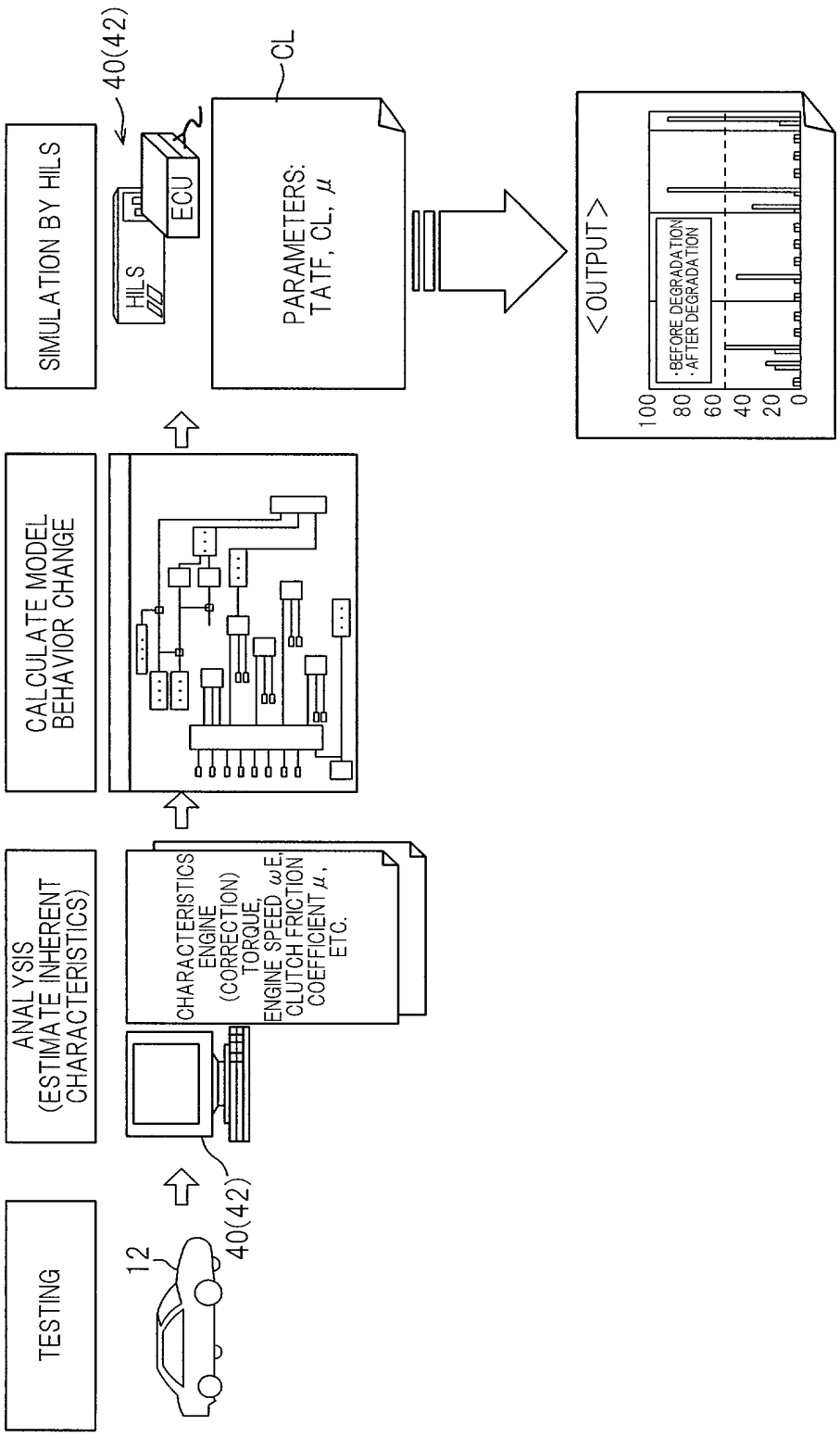

TESTING
ANALYSIS
(ESTIMATE INHERENT
CHARACTERISTICS)
CALCULATE MODEL
BEHAVIOR CHANGE
SIMULATION BY HILS
12
40(42)
CHARACTERISTICS
ENGINE
(CORRECTION)
TORQUE,
ENGINE SPEED ωE,
CLUTCH FRICTION
COEFFICIENT μ,
ETC.
40(42)
HILS
ECU
CL
PARAMETERS:
TATF, CL, μ
<OUTPUT>
·BEFORE DEGRADATION
·AFTER DEGRADATION
100
80
60
40
20
0

FIG. 25

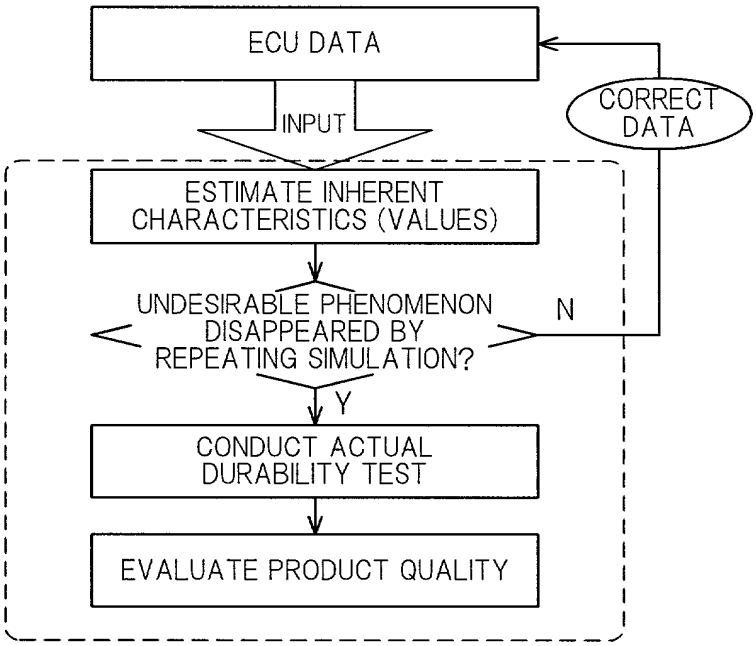
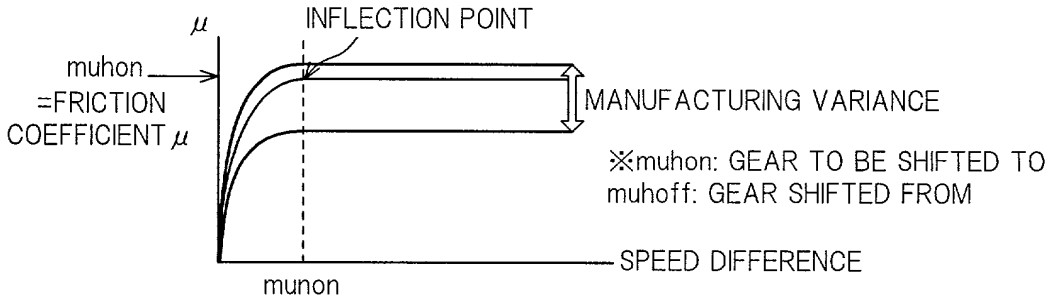

ECU DATA
INPUT
CORRECT DATA
ESTIMATE INHERENT CHARACTERISTICS (VALUES)
UNDESIRABLE PHENOMENON DISAPPEARED BY REPEATING SIMULATION?
N
Y
CONDUCT ACTUAL DURABILITY TEST
EVALUATE PRODUCT QUALITY

FIG. 26A

34up	1/8	2/8	4/8	6/8	8/8
23up	1/8	2/8	4/8	6/8	8/8
12up	1/8	2/8	4/8	6/8	8/8
muhon	0.147	0.145	0.133	0.123	0.125
muhoff	0.15	0.14	0.14	0.13	0.14
munon[rpm]	300	600	600	600	1300
munoff[rpm]	50	50	50	50	50
TE CORRECTION BEFORE SHIFTING[kgf·m]	−1	−1	−1	−1	−1
TE CORRECTION AFTER SHIFTING[kgf·m]	−1	−1	−1	−1	−1

FIG. 26B



=FRICTION COEFFICIENT INFLECTION POINT SPEED DIFFERENCE

FIG. 26C

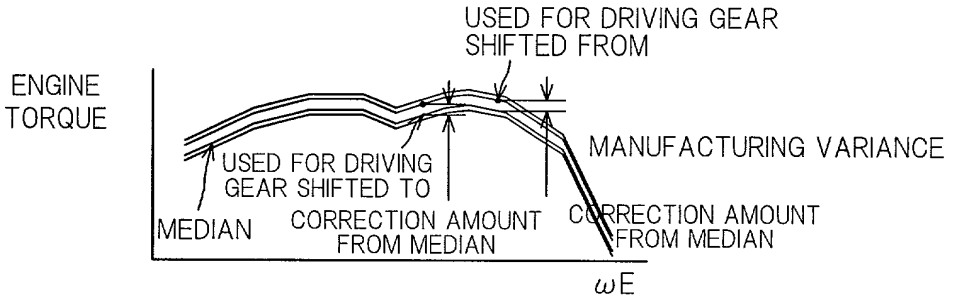


FIG. 27

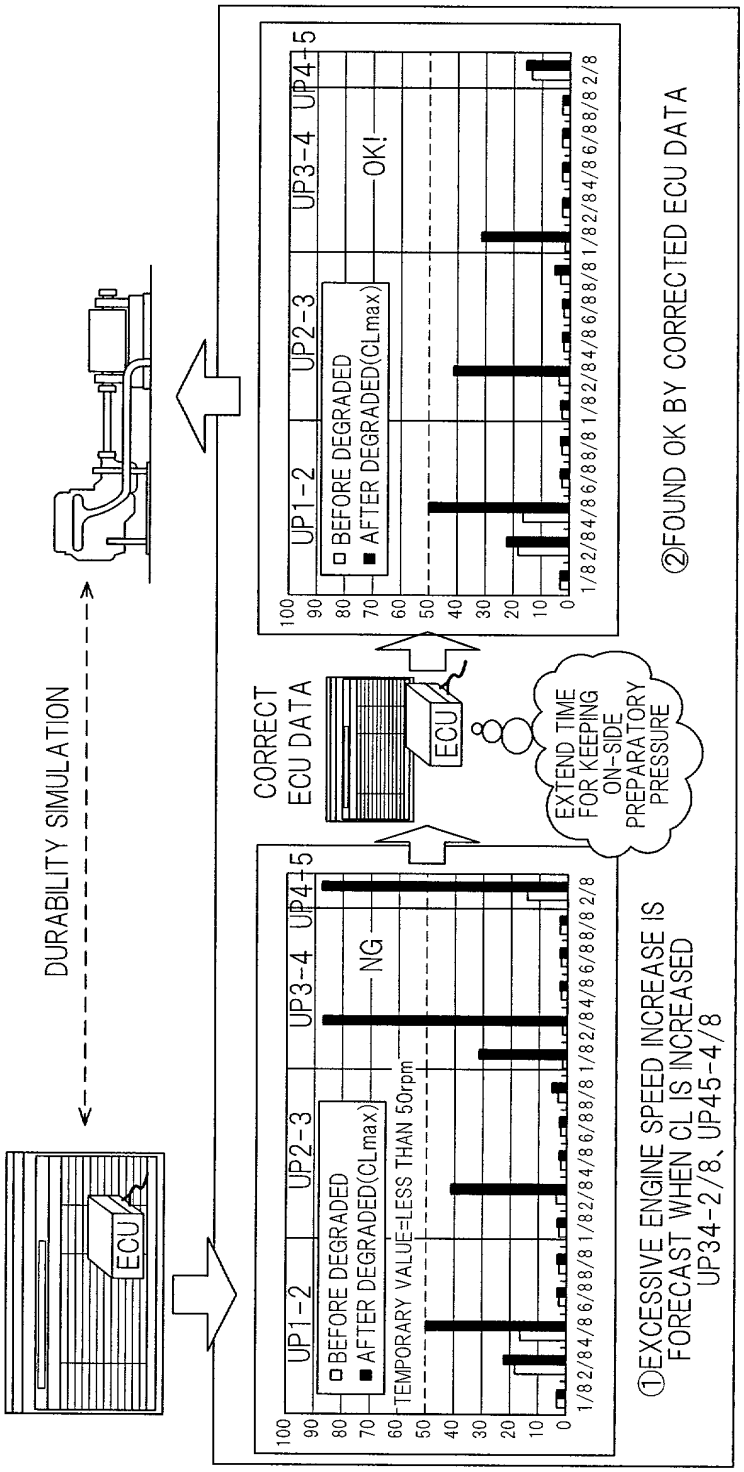

ECU DATA
ECU
DURABILITY SIMULATION
UP1-2
UP2-3
UP3-4
UP4-5
BEFORE DEGRADED
AFTER DEGRADED(CLmax)
TEMPORARY VALUE=LESS THAN 50rpm
NG
1/8 2/8 4/8 6/8 8/8 1/8 2/8 4/8 6/8 8/8 1/8 2/8 4/8 6/8 8/8 2/8
①EXCESSIVE ENGINE SPEED INCREASE IS FORECAST WHEN CL IS INCREASED UP34-2/8、UP45-4/8
CORRECT ECU DATA
EXTEND TIME FOR KEEPING ON-SIDE PREPARATORY PRESSURE
OK!
②FOUND OK BY CORRECTED ECU DATA

FIG. 28

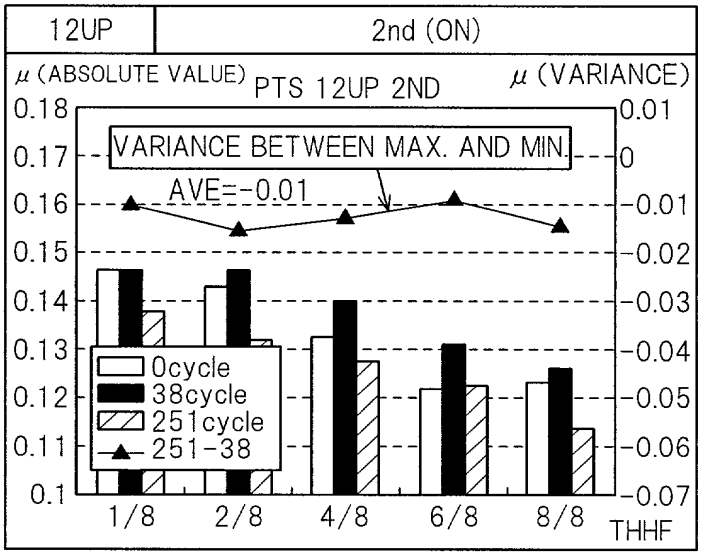

12UP
2nd (ON)
μ (ABSOLUTE VALUE)
PTS 12UP 2ND
μ (VARIANCE)
VARIANCE BETWEEN MAX. AND MIN.
AVE=-0.01
0cycle
38cycle
251cycle
251-38
0.18
0.17
0.16
0.15
0.14
0.13
0.12
0.11
0.1
0.01
0
-0.01
-0.02
-0.03
-0.04
-0.05
-0.06
-0.07
1/8
2/8
4/8
6/8
8/8
THHF

FIG. 29

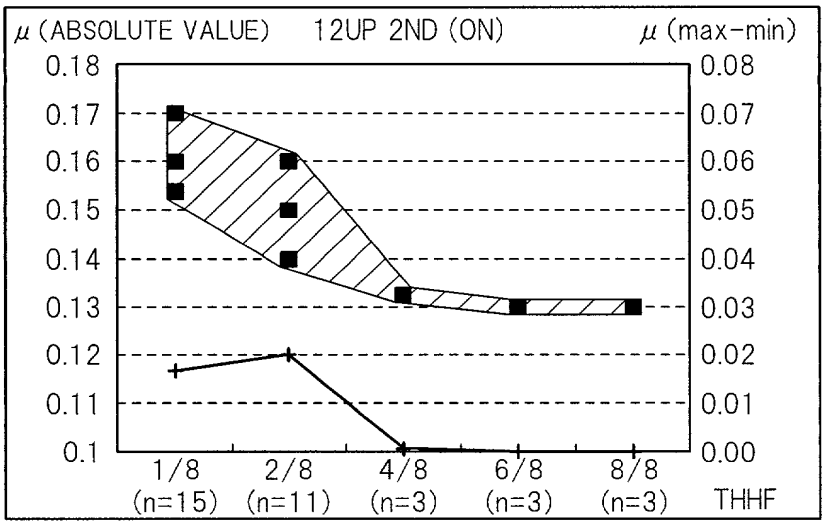

μ (ABSOLUTE VALUE)
12UP 2ND (ON)
μ (max-min)
0.18
0.17
0.16
0.15
0.14
0.13
0.12
0.11
0.1
0.08
0.07
0.06
0.05
0.04
0.03
0.02
0.01
0.00
1/8 (n=15)
2/8 (n=11)
4/8 (n=3)
6/8 (n=3)
8/8 (n=3)
THHF

FIG. 30

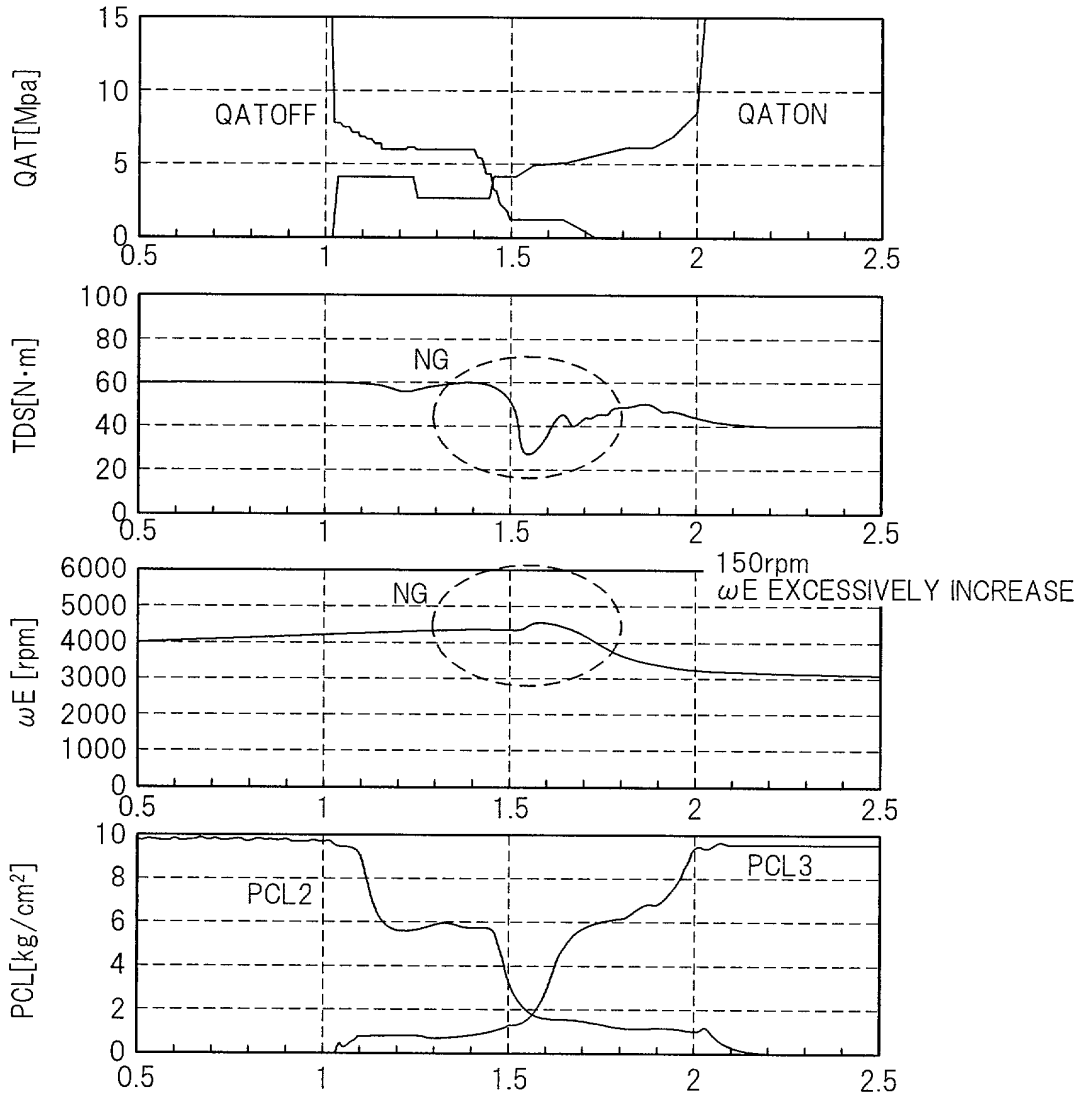

QAT[Mpa]
15
10
5
0
QATOFF
QATON
0.5
1
1.5
2
2.5
TDS[N·m]
100
80
60
40
20
0
NG
ωE [rpm]
6000
5000
4000
3000
2000
1000
0
NG
150rpm
ωE EXCESSIVELY INCREASE
PCL[kg/cm²]
10
8
6
4
2
0
PCL2
PCL3

FIG. 31

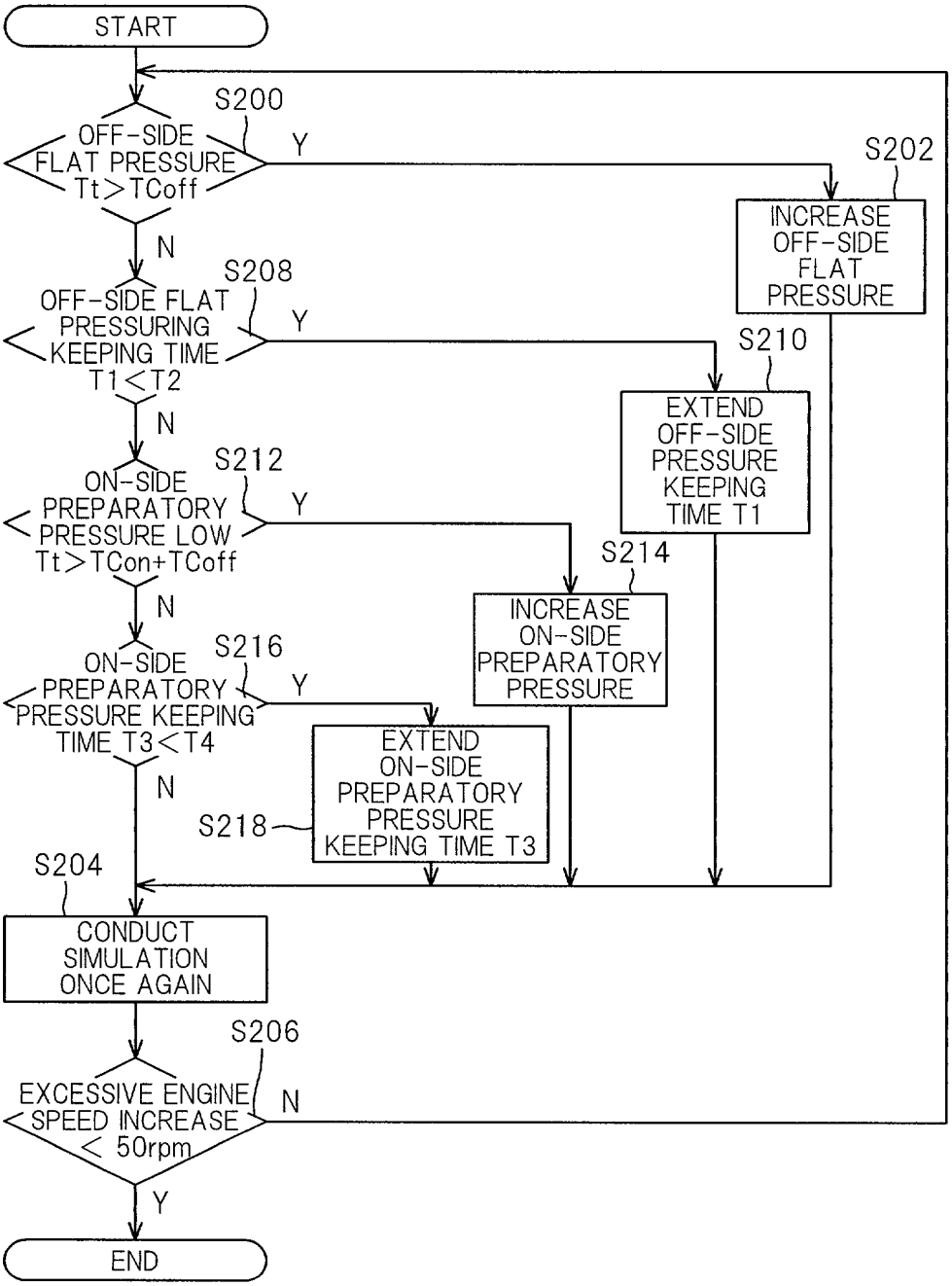

START
S200
OFF-SIDE FLAT PRESSURE Tt>TCoff
Y
S202
INCREASE OFF-SIDE FLAT PRESSURE
N
S208
OFF-SIDE FLAT PRESSURING KEEPING TIME T1<T2
Y
S210
EXTEND OFF-SIDE PRESSURE KEEPING TIME T1
N
S212
ON-SIDE PREPARATORY PRESSURE LOW Tt>TCon+TCoff
Y
S214
INCREASE ON-SIDE PREPARATORY PRESSURE
N
S216
ON-SIDE PREPARATORY PRESSURE KEEPING TIME T3<T4
Y
EXTEND ON-SIDE PREPARATORY PRESSURE KEEPING TIME T3
S218
N
S204
CONDUCT SIMULATION ONCE AGAIN
S206
EXCESSIVE ENGINE SPEED INCREASE < 50rpm
N
Y
END

FIG. 32

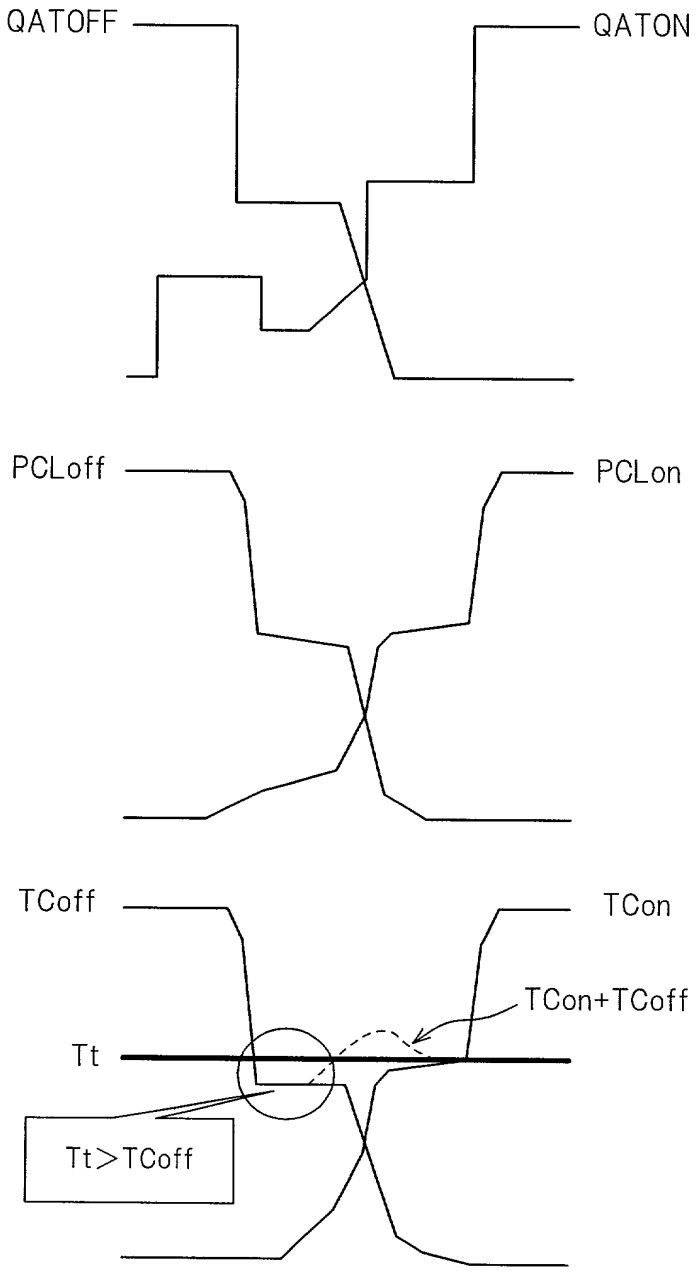


FIG. 33

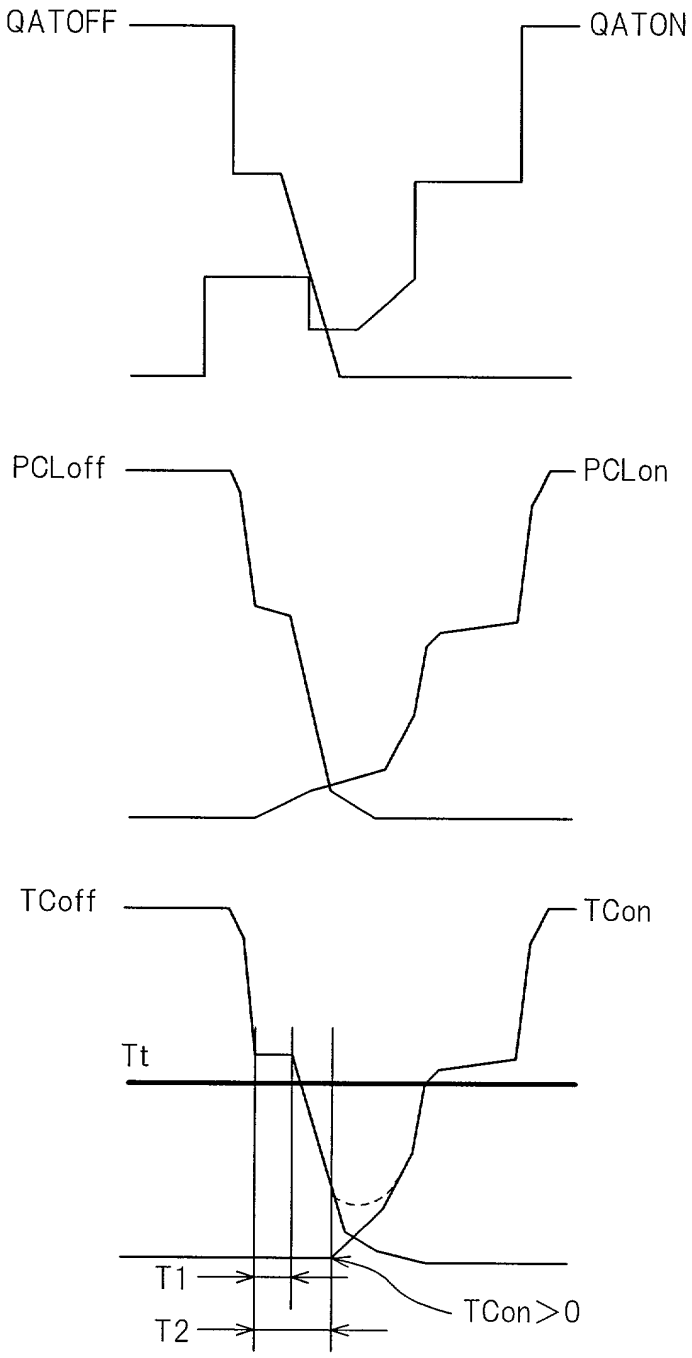


FIG. 34

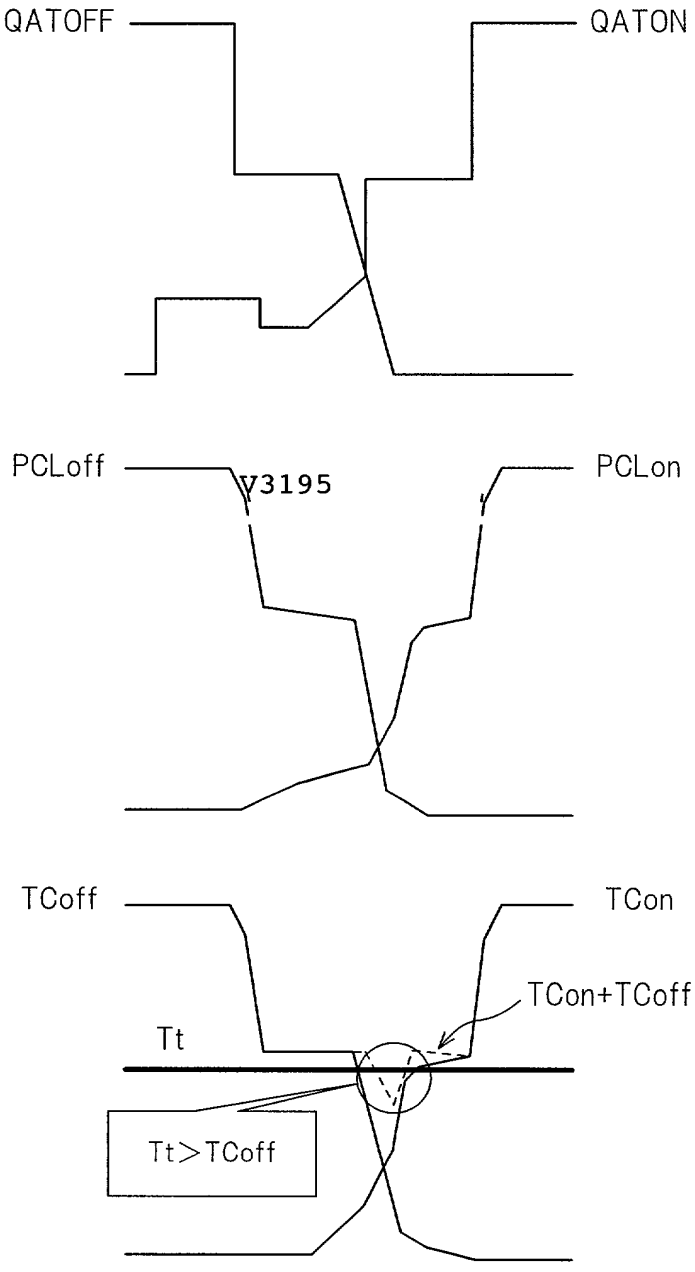

QATOFF
QATON
PCLoff
V3195
PCLon
TCoff
TCon
TCon+TCoff
Tt
Tt>TCoff

FIG. 35

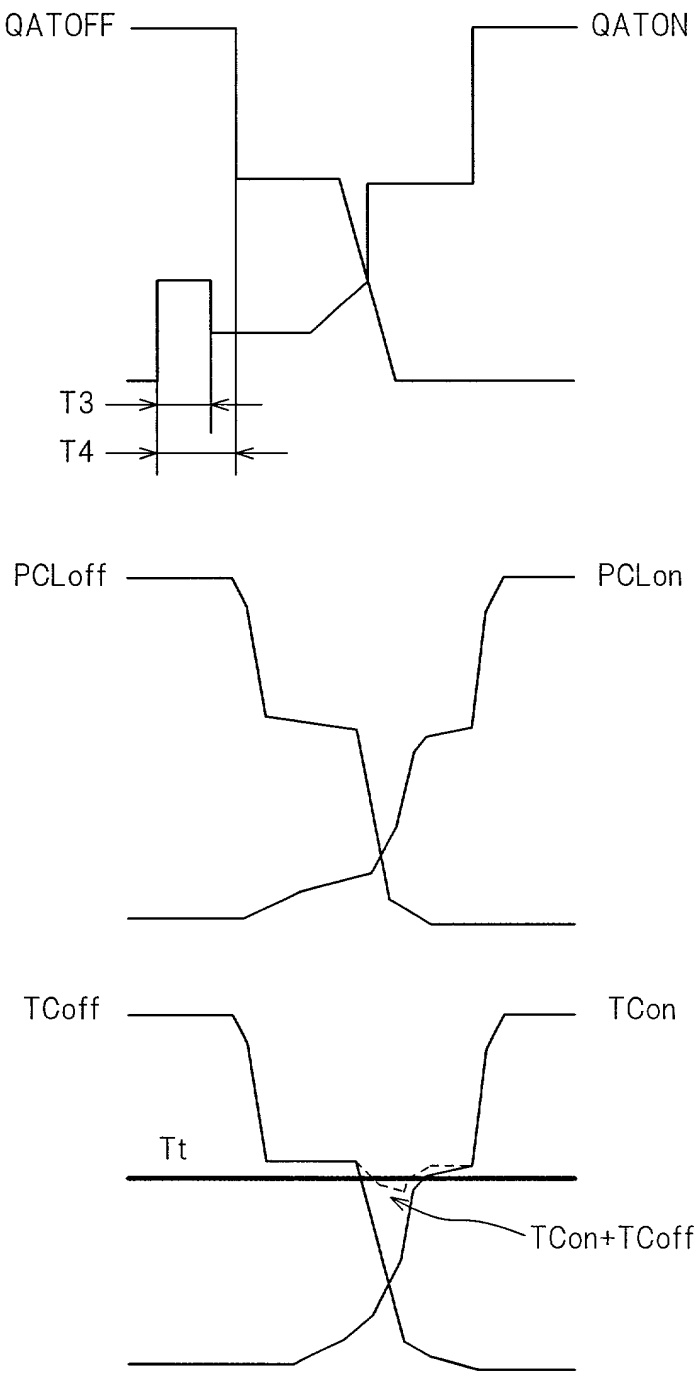


FIG. 36

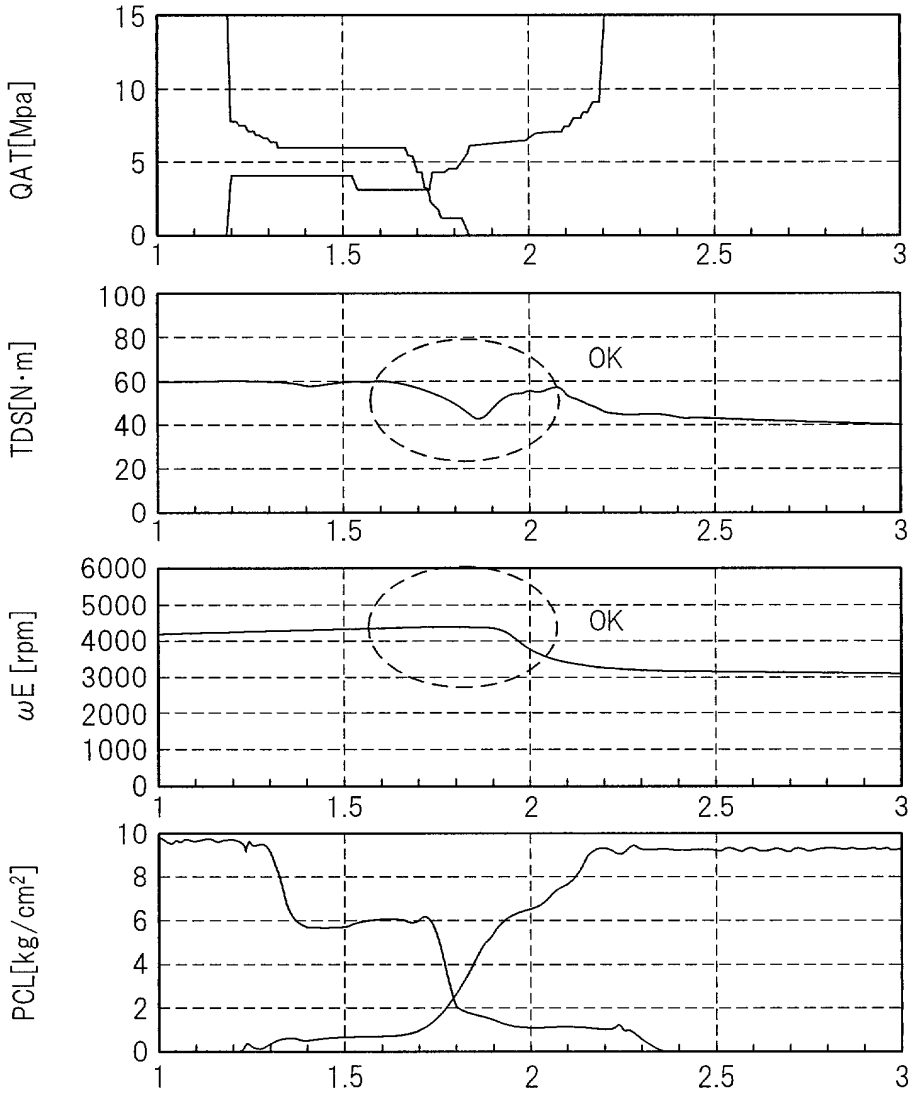
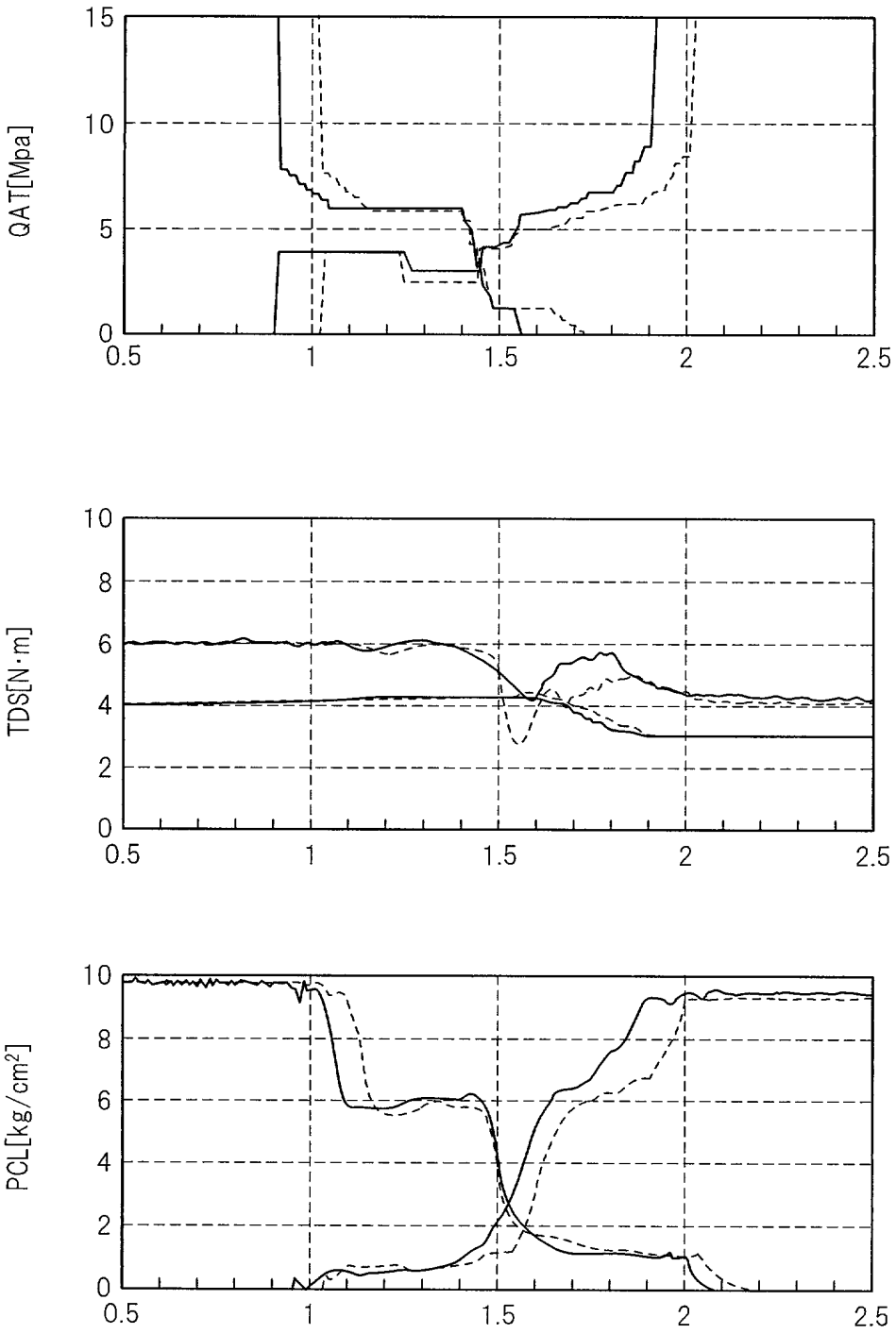

QAT[Mpa]
15
10
5
0
1
1.5
2
2.5
3
TDS[N·m]
100
80
60
40
20
0
OK
ωE [rpm]
6000
5000
4000
3000
2000
1000
0
OK
PCL[kg/cm²]
10
8
6
4
2
0

FIG. 37


QAT[Mpa]
15
10
5
0
0.5
1
1.5
2
2.5
TDS[N·m]
10
8
6
4
2
0
0.5
1
1.5
2
2.5
PCL[kg/cm²]
10
8
6
4
2
0
0.5
1
1.5
2
2.5